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NEWS AND INFORMATION

IAOS Annual Meeting

The 2010 IAOS annual meeting will be held from 3:30-5:00pm on Friday, April 16, 2010 at the SAA meetings in St. Louis, MO. Consult your SAA program for meeting room location.

CONSIDER PUBLISHING IN THE IAOS BULLETIN

The *Bulletin* is a twice-yearly publication that reaches a wide audience in the obsidian community. Please review your research notes and consider submitting an article, research update, news, or lab report for publication in the IAOS *Bulletin*. Articles and inquiries can be sent to cdillian@princeton.edu. Thank you for your help and support!

IAOS Membership Renewal

In 2008, the IAOS transitioned all IAOS annual memberships to a Jan. 1 – Dec. 31 calendar year. So all IAOS memberships for 2010 can be renewed starting on Jan. 1, 2010. You can renew online via PayPal on the IAOS website at <http://www.peak.org/obsidian> or simply use the form on the last page of this Bulletin. Renewing your membership will allow the IAOS to continue, and we appreciate your support.

Regards,
Colby Phillips, IAOS Secretary/Treasurer

NOTES FROM THE PRESIDENT

Happy Holidays to all at the close of 2009. This past October, the Geological Society of America conference provided an opportunity for several IAOS members to gather in Portland, Oregon, where Ellery Frahm and Joshua Feinberg co-organized a session comingling archaeological and geological perspectives on obsidian. Congratulations to Ellery and Joshua on a great session.

We had a number of members attend the IAOS 2009 annual meeting at the SAAs in Atlanta, Georgia. During the meeting, our changes to the IAOS bylaws received unanimous acceptance. The full text of the by-laws are reprinted here at the end of the Winter 2010 Bulletin.

By the time of the Summer 2010 Bulletin, Tristan Carter will be in place as IAOS President. I encourage all IAOS members to contact him with new ideas and ambitions for the organization. Please plan to join us in welcoming Dr. Carter at the annual IAOS business meeting at the SAA meetings in St. Louis, 3:30-5:00 p.m. on Friday April 16, 2010.

Sincerely,

Ana Steffen
asteffen@vallescaldera.gov
President, IAOS

38th International Symposium on Archaeometry

The 38th International Symposium on Archaeometry will be held at the University of South Florida, Tampa, May 10-14, 2010. The aim of ISA is to promote the integration of scientific techniques with archaeology and cultural heritage, with participants coming from a variety of backgrounds and subdisciplines. The website (<http://isa2010.cas.usf.edu/>) includes preliminary information, including title/abstract submission and registration deadlines. Additional information on accommodations, payment methods, social activities, publication, sponsors, etc. will be added in the near future.

Contact: Robert H. Tykot, Chairman of the Local Organizing Committee, rtykot@cas.usf.edu

CURVE-FITTING FOR OBSIDIAN LABORATORY HYDRATION ANALYSIS: A CAUTIONARY TALE

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Abstract

Curve-fitting, usually as a linear least-squares best fit, is a key step in analysis of obsidian laboratory hydration data, to estimate obsidian activation energy and pre-exponential factor from measurements of hydration rim, hydration time, and temperature. Unfortunately, application of the simple equations for linear best fit found in elementary textbooks, or of the linear best fit functions in MS Excel, can lead to incorrect answers because of assumptions made in deriving the equations which are not visible to the user. This short paper describes the three major problems affecting use of these equations and MS Excel in obsidian hydration analysis, and shows how they can be minimized or avoided.

Introduction

Curve-fitting, typically implemented as a linear least-squares best fit, is required in analysis of obsidian laboratory hydration data, employed for estimating obsidian activation energy and pre-exponential factor. Many elementary textbooks on statistics and data analysis contain a set of simple equations for linear best fit (e.g. Hoel 1976:222ff.), and these same equations are implemented as functions in MS Excel. Unfortunately, naïve application of these equations or of the linear best fit features in Excel (LINBEST, SLOPE, INTERCEPT) can lead to incorrect answers because of assumptions built into the equations which are not visible to the user. These assumptions do not affect Excel in its primary intended use, which is business analysis, but can cause problems in scientific analysis; scientifically-oriented analysis programs such as SIGPLOT[®] or PSIPLOT[®] do not have these same limitations. These issues are well known in the physics and physical chemistry communities (see, e.g. Cvetanovic et al. 1979), but are not as commonly understood by archaeologists.

In this short paper I present a summary of the problem, largely derived from the material

of Cvetanovic et al. 1979, which is not generally available to archaeologists (nor is it easy to read, unless the reader has a good grasp of advanced mathematics). I also provide a description of how to solve the problems for the two cases mentioned above. I have tried to keep the mathematics to a minimum by omitting derivations, but it cannot be avoided entirely, since the problem is inherently mathematical. Those obsidian researchers who are not mathematically inclined are advised at least to read the text, prior to handing over the analysis dirty work to an assistant.

Linear Best Fit Theory

The idea of a linear best fit is to construct a straight line through data containing experimental errors in such a way as to satisfy some criterion of “goodness”. The usual criterion is to minimize the sum-square error in the dependent variable (y dimension) between the best fit line and the data points, weighted by the error variance of each point (Meyer 1975:74). This is expressed mathematically as

$$\min \chi^2 = \min \sum_{i=1}^N \frac{(y_i - \bar{y}_i)^2}{\sigma_{yi}^2}, \quad (1)$$

where χ^2 is the sum-square error in y , y_i is the i^{th} data point, \bar{y}_i is the corresponding y value of the best-fit line, σ_{yi}^2 is the error variance in the y dimension associated with the i^{th} data point, and N is the number of data points. Note that σ_{yi}^2 is not the same as the instantaneous error for that point; rather, it is a characteristic of the population from which the point was drawn (Cvetanovic et al. 1979; Guest 1961).

Examination of equation 1 shows that the squared error for each data point is weighted by the reciprocal of its corresponding error variance; thus, if a given data point comes from a population with large error variance, it is not weighted as heavily as one with a small error variance; put another way, points with low error variance are assigned greater confidence than those with higher error variance. This weighting by error variance is omitted from elementary treatments of linear best fit, and is not implemented as a function in MS Excel, which assumes uniform weighting on all data points.

The best-fit line is represented by an equation of the form

$$\bar{y}_i = mx_i + b, \quad (2)$$

so equation 1 can be written as

$$\min \chi^2 = \min \sum_{i=1}^N \frac{(y_i - mx_i - b)^2}{\sigma_{yi}^2}. \quad (3)$$

The problem then becomes one of determining the values of slope (m) and y -intercept (b) that minimize χ^2 for the given data set. The calculation procedure involves taking the partial derivative of χ^2 with respect to m and with respect to b and setting each equal to

zero; this leads to two equations in two unknowns (m and b), which can be solved. The procedure is shown in many advanced textbooks (e.g. Guest 1961:14ff; Meyer 1975:74-75; Taylor 1982:153ff). The resulting formulas for m and b are

$$m = \frac{EB - CA}{DB - A^2} \quad (4)$$

and

$$b = \frac{DC - EA}{DB - A^2}, \quad (5)$$

where

$$A = \sum_{i=1}^N w_i x_i, \quad (6a)$$

$$B = \sum_{i=1}^N w_i, \quad (6b)$$

$$C = \sum_{i=1}^N w_i y_i, \quad (6c)$$

$$D = \sum_{i=1}^N w_i x_i^2, \quad (6d)$$

$$E = \sum_{i=1}^N w_i x_i y_i; \quad (6e)$$

the weights w_i are given by

$$w_i = \frac{1}{\sigma_{yi}^2}. \quad (6f)$$

If the y -intercept is known to be equal to zero, the equation for the slope becomes simply

$$m = E/D \quad (7)$$

These equations (4 – 6f) represent the slope (m) and y-intercept (b) of the best fit line for the data set, based on the criterion of equation 1; equation 7 gives the slope when the y-intercept is known to be zero. *It is explicitly assumed that all errors are in the y variable, and the x variable is error-free; this is a good approximation in some cases but not in all. It is probably reasonable for laboratory hydration analysis. This is the first fundamental limitation of the simple equations and MS Excel.*

Equations 4–6f can be easily programmed into MS Excel, but they are not implemented as functions; instead, MS Excel automatically assumes that $w_i = 1$ for all values of i . *Weighting by error variance becomes important if the data points are each characterized by differing sample sizes, which often occurs, or if the analyst is combining data collected by different researchers using differing techniques, in which confidence levels vary. This is the second fundamental limitation to the simple equations and the linear best fit functions in MS Excel.*

On the other hand, the weighting may be simplified if the analyst has reason to believe that all data points have essentially the same error variance; in that case w_i may be set equal to one, and equation 6b becomes $B = N$, the number of data points.

Issues in Obsidian Hydration Analysis

The situation with analysis of laboratory obsidian hydration data is more complex because the linear fit is made to a composite variable, made up of other variables. Here the objective is to compute the activation energy and pre-exponential factor from recorded data on hydration rim thickness r , hydration temperature T , and time t . The temperature dependence of the hydration rate is approximately described by the Arrhenius equation

$$k = k_0 e^{-E/RT}, \quad (8)$$

where k is hydration rate at temperature T , k_0 is the pre-exponential factor, E is activation energy, and R is the universal gas constant per mole. If equation 8 is substituted into equation 1, the result is

$$r^2 = tk_0 e^{-E/RT} \quad (9)$$

By rearranging the equation and taking the natural logarithm of both sides, we get

$$\ln\left(\frac{r^2}{t}\right) = \ln(k_0) - \frac{E}{RT}. \quad (10)$$

If we now define composite variables by setting $x = 1/T$ and $y = \ln(x^2/t)$, equation 10 becomes

$$y = \ln(k_0) - \left(\frac{E}{R}\right)x. \quad (11)$$

This is now a linear equation with slope $-E/R$ and y-intercept $\ln(k_0)$, and can be solved by equations 4 – 6f.

However, the weighting factors (equation 6f) must be modified to put them in terms of r instead of y , because we want to minimize errors in r . The method for doing this is known as the theory of propagation of errors (Taylor 1982:153ff), by which it can be shown that, with y defined as $\ln(x^2/t)$, and assuming the majority of error is caused by errors in the reading of r (supporting analysis in Rogers 2006), the weighting factors are

$$w_i = r_i^2 / \sigma_{ri}^2 \quad (12)$$

where σ_{ri}^2 is the error variance in hydration rim r . This is known as “change-of-variable” weighting, and its effect in this case is to increase the weight placed on data points with high values of r . The theory of propagation of errors further shows that the exact form of the change of variable weights is a function of the

form of the composite variable, i.e. equation 12 applies only to the case of $y = \ln(r^2/t)$. (Cvetanovic et al. 1979).

The significance of the change of variable weighting factors is that they ensure that the sum-square error in r is minimized. If such weighting is not used, the best fit procedure will minimize the error in $\ln(r^2/t)$ instead, which will yield incorrect values for E/R and k_0 . Change of variable weighting is not included in the simple textbook equations, nor is it a function in MS Excel, and is the third reason why naïve use of MS Excel can give a wrong answer in obsidian analysis.

The equations to be solved are now

$$-\frac{E}{R} = \frac{EB - CA}{DB - A^2} \quad (13)$$

and

$$\ln(k_0) = \frac{DC - EA}{DB - A^2}, \quad (14)$$

where

$$A = \sum_{i=1}^N \left[\left(\frac{r_i^2}{\sigma_{ri}^2 T_i} \right) \right], \quad (15a)$$

$$B = \sum_{i=1}^N \left[\left(\frac{r_i^2}{\sigma_{ri}^2} \right) \right], \quad (15b)$$

$$C = \sum_{i=1}^N \left[\left(\frac{r_i^2}{\sigma_{ri}^2} \right) \ln \left(\frac{r_i^2}{t_i} \right) \right], \quad (15c)$$

$$D = \sum_{i=1}^N \left[\left(\frac{r_i^2}{\sigma_{ri}^2 T_i^2} \right) \right], \quad (15d)$$

and

$$E = \sum_{i=1}^N \left[\frac{r_i^2}{\sigma_{ri}^2 T_i} \ln \left(\frac{r_i^2}{t_i} \right) \right]. \quad (15e)$$

Equations 15a – e as written contain weighting for both variable error variance (the factor of $1/\sigma_{ri}^2$) and change of variable (the factor of r_i^2). If the error variance for all data points is the same, the σ_{ri}^2 can all be set equal to unity.

Although these equations look forbidding, they can be quite easily set up as an Excel spread-sheet, starting with four columns listing values of r_i , t_i , σ_{ri} , and T_i , followed by five columns to compute the quantities in square brackets in equations 19a – e. The latter five columns are then summed to yield parameters A through E, and the values of E/R and $\ln(k_0)$ computed from the sums by equations 13 and 14.

Use of this technique is especially important in laboratory obsidian studies because values of k for archaeological temperatures are computed by extrapolation of equation 8 from laboratory temperatures, and are extremely sensitive to errors in the values of k_0 and E . Even if the analyst assumes all σ_{ri} are equal it is essential to include the change of variable weighting; otherwise, once again the least-squares procedure will minimize the error in the composite variable instead of the error in r .

Numerical Example

As a simple numerical example, I analyze the data set published by Stevenson and Scheetz (1989) with and without change of variable weighting. This is not meant as a criticism of Stevenson and Scheetz, but their material is simply one of the few examples of a published data set to use as a test case. Table 1 presents the laboratory hydration data from Coso 4-1 (Stevenson and Scheetz 1989:25, Table 1).

Table 1. Laboratory hydration data for Coso 4-1

Hydration Temperature, °C	Hydration Time, days	Hydration Rim, μ
160	3	3.72
160	6	5.05
160	12	6.90
160	18	8.90
130	12	2.95
140	12	3.77
170	12	8.76

In the calculations the error variances were all assumed to be equal, since there was no evidence to the contrary. Two sets of calculations were made. The first was without change of variable weighting, in which the slope and y-intercept were computed using equations 4-6 with $x = 1/T$ and $y = \ln(x^2/t)$. The second applied change of variable weighting per equations 13 – 15. The parameters computed were activation energy (E), pre-exponential factor (k_0), and the hydration rate extrapolated to 20°C, a typical archaeological temperature (k_{20}). Table 2 presents the results.

Table 2. Comparison of obsidian parameters, showing effect of change of variable weighting.

Parameter	Units	Without COV Weighting	With COV Weighting
E	J°K/mol	85738	82060
k_0	μ^2/yr	$3.295 \times 10_{13}$	$1.174 \times 10_{13}$
k_{20}	$\mu^2/1000 \text{ yrs}$	17.36	28.01

Table 2 shows clearly that use of change of variable weighting can have a significant effect on the numerical results; in this case, almost a factor of two in the archaeological hydration rate. Parenthetically, I was unable to duplicate the numerical results of Stevenson and Scheetz, because their article did not describe the analytic process in detail; however, the results in Table 2 with change of variable weighting are very close to their

results (Stevenson and Scheetz 1989:26, Table 2).

Conclusions

The purpose of this paper has been to indicate three of the problems which can bite the unwary user of simple textbook equations, or MS Excel functions, for linear best fit in doing obsidian laboratory hydration analysis, and show how they can be avoided or minimized.

The first issue is that the simple procedures for linear best fit assume the independent variable to be error-free. The rigorous solution is known as the Total Least Squares algorithm (Van Huffel and Vandewalle 1991), but is so complex to implement for this case as to be impractical. The problem can be minimized in practice by choosing the variable with the smaller coefficient of variation ($CV = \text{standard deviation}/\text{mean}$) to be the independent variable. For laboratory hydration, $1/T$ generally has smaller errors than $\ln(r^2/t)$, and should be chosen as the independent variable, as indeed it usually is. In any particular case it may be necessary to perform an error analysis to make this choice.

The second issue is that the simple equations, and the best fit functions in MS Excel, explicitly assume that the error variances of all data points are equal. This is sometimes a good assumption, but not always. If it is not, the solution is for the analyst to construct a spread-sheet which implements the equations with point-specific variances.

The third issue is more serious for laboratory obsidian studies: the simple equations and MS Excel do not include change-of-variable weighting, which is critical when composite dependent variables are used. *With a composite dependent variable, there are no cases in which ignoring change-of-variable weighting is justified.* The solution again is for the analyst to construct a spread-sheet which implements the equations with

point-specific weights, including change of variable.

It should be added that if the analysis is performed using a scientific package such as PSIPLOT[®], SPSS[®], or equivalent, the change of variable weighting is automatically included when you choose a logarithmic fit, in which case the cautions expressed in this paper are unnecessary.

As a final point, and a *mea culpa*, I failed to take change-of-variable weighting into account in my simulation-based error analysis of laboratory hydration, which accounts for the shift in the mean error I observed with increasing measurement error variance (Rogers 2006). My conclusions in that paper are valid for any analysis which omits change-of-variable weighting, but do not apply to any analysis which includes it.

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REPORT ON THE CHOGABON SITE, A NEW SOURCE OF OBSIDIAN ARTIFACTS IN WEST-CENTRAL IRAN

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Abstract

Obsidian tools, in addition to Chalcolithic pottery, were recovered during the recent survey of the Chogabon site in the Iranian province of Lorestan. Ten obsidian artifacts were selected for wavelength-dispersive XRF analysis, which indicated that these tools were not made from obsidian sources available in northwestern Iran, and may represent new and unidentified sources. Key words: Iran, obsidian, Chogabon, WD-XRF.

Introduction

Obsidian was utilized as a raw material for stone tool production from the end of the Mesolithic up to the Iron Age in Iran, and was transported and traded widely among tool-making centers in the greater Mesopotamia region (Rosen et al., 2005). At the newly discovered site of Chogabon in the Lorestan province of west-central Iran, obsidian artifacts including cores and flakes have been recovered, indicating that obsidian tools were produced at the site (Far 2006). Based on the presence of obsidian cores, the long distances between the Chogabon site and known obsidian sources in northwestern Iran, and a lack of evidence for trade and cultural interaction with more distant sites in Mesopotamia and Anatolia, it is proposed that these artifacts were made from obsidian sources located near the site.

Study Area

The Chogabon site is located 45 km west of the town of Kohdasht in the Lorestan province of west-central Iran (Figures 1 and

2). The site covers an area roughly 800 x 300 meters with mounds up to 10 meters tall, and it is possibly the largest currently known Neolithic site in the Lorestan province. The elevation of the site is 1006 meters ASL in a temperate climate that supports abundant agriculture, with water fed by the nearby Khosrow Abad River. Chogabon is situated at the intersection of three important valleys, providing access to trade and exchange relationships in three directions from the site. The site was surveyed in the winter of 2005. During the survey, a large number of Neolithic and Chalcolithic potsherds were recorded, indicating a settlement with significant time depth (Far 2006). Most of the recent excavations of other sites in this region have recovered obsidian stone tools, including cores and flakes representative of stone tool manufacturing processes and activities.

Methods

In order to test the hypothesis that obsidian tools from the Chogabon site were made from

Figure 1: Site location, Lorestan Province, west-central Iran.



Figure 2: Site is located 45 km west of the town of Kohdasht, Lorestan Province, Iran.

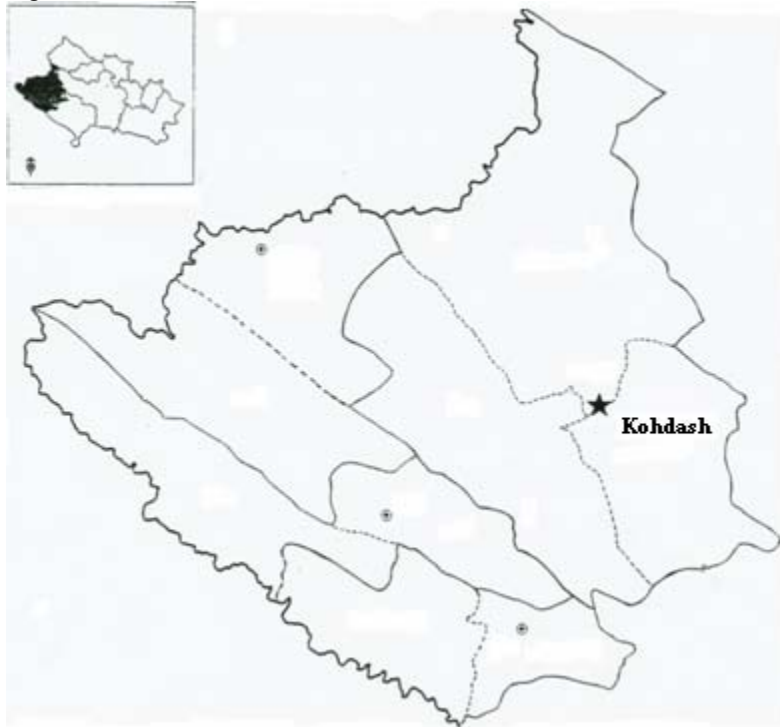


Table 1: Results of WD-XRF Analysis.

Sample No.	1	2	3	4	5	6	7	8	9	10
CaO	0.179	0.193	0.193	0.207	0.207	0.208	0.225	0.345	0.355	0.211
Fe₂O₃	2.551	2.571	2.622	2.669	2.669	2.755	2.774	3.025	2.929	5.331
Rb	0.015	0.017	0.017	0.021	0.019	0.018	0.016	0.046	0.019	0.021
Zr	0.08	0.094	0.082	0.107	0.109	0.098	0.073	0.266	0	0.107
NaO₂	4.805	4.766	4.733	4.699	4.859	4.639	4.702	4.804	4.795	4.643
Al₂O₃	10.43	10.41	10.37	10.54	10.37	10.281	10.257	10.17	10.07	10.36
SiO₂	77.32	77.97	76.72	77.28	77.03	77.206	76.795	76.94	76.99	76.6
SO₃			0.048		0.036			0.205	0.058	0.048
Cl	0.115	0.12	0.111	0.111	0.125	0.111	0.124	0.136	0.117	0.124
K₂O	4.12	4.143	4.197	4.264	4.262	4.35	4.318	4.387	4.436	4.264
MgO	0.069			0.069		0.068	0.072	0.092		0.074
P₂O₅		0.016	0.766				0.023			0.723
TiO₂	0.147	0.137	0.131	0.151	0.16		0.147			0.151
ZrO₂									0.222	
Y	0.008	0.009	0.008	0.009	0.01	0.011				0.009
W	0.064	0.092	0.051							
MnO	0.057	0.068			0.062		0.075			
Zn	0.043									
Ni							0.029			

locally available obsidian sources, ten artifacts were chosen for geochemical analysis using wavelength dispersive X-ray fluorescence (WD-XRF). Flakes that had no diagnostic qualities were prepared into powdered capsules for analysis with a Philips PW2404 WD-XRF instrument.

Results and Discussion

Results of the WD-XRF analysis of ten obsidian artifacts from the Chogabon site are listed in Table 1. Based on the analyses conducted here and using the values for Rb and Zr to differentiate groups of artifacts, it appears that two obsidian sources may be

represented in the sample assemblage. Currently, these samples do not match published data on known obsidian sources located in Armenia, Cappadocia (Turkey), northwestern Iran, or the Caucasus (Blackman 1984; Gratuze 1999), which are all located long distances from the Chogabon site. Based on an analysis of the Chogabon assemblage, it is clear that the site was a center for stone tool production, and it is inferred that obsidian was brought to the site from locally available sources. However, these sources are currently unknown, and should be the focus of further archaeological and geological investigation in the Lorestan region.

Acknowledgements

We would like to thank the Faculty of Basic Science at the Institute of Archaeology of Tehran which conducted the WD-XRF analyses for this study. The survey of the Chogabon site was funded by a grant (#19205) from the Institute of Archaeology of Tehran.

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HOW DID PALEOTEMPERATURE CHANGE AFFECT OBSIDIAN HYDRATION RATES?

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Abstract

The position of the hydration front in an obsidian artifact is the integrated result of the thermal history of the artifact; thus it should reflect the effects of paleotemperature variation. This paper reports the results of a computer-based model of obsidian hydration, including a model of paleotemperature variation based on published data. It is found that the generally increased temperatures of the altithermal led to an increase in effective hydration constant of approximately 7% for artifacts in the 6,000 – 8,000 year range; furthermore, the Little Ice Age is found to have a significant effect. A computational method to compensate for this effect when estimating ages by obsidian hydration dating is described.

Introduction

If an obsidian artifact is measured today, its hydration rim is the result of an integrated value of hydration rate over the time since it was created; thus, it should reflect the effects of paleotemperature change. This paper evaluates the effects of long-term paleotemperature changes on obsidian effective hydration temperature (EHT), based on the EHT methodology of Rogers (2007a). The variation of mean temperature over Holocene time scales is based on the Anathermal-Altithermal-Medithermal sequence of Antevs (1955), with quantitative estimates based on West et al. (2007), Graumlich (1993), and Soon and Baliunas (2003). It is recognized that higher-frequency temperature fluctuations also occurred; however, for the purposes of obsidian modeling only oscillations with periods greater than 500 – 1,000 years are considered. Conditions typical of the southwestern Great Basin and northern Mojave Desert are assumed.

Obsidian Hydration Model

The hydration process in obsidian (or any other glass) is a diffusion-reaction process

(Doremus 2000, 2003): “diffusion” because the time rate of change of the concentration of diffusing water at any point is proportional to the spatial rate of change of the concentration gradient; “reaction” because a portion of the diffusing water molecules reacts chemically with the glass matrix and is lost to the diffusion process. For the case of diffusion into a semi-infinite medium (the archaeological hydration case) the concentration of diffusing water molecules is described by the equation

$$\partial C/\partial t = \partial/\partial x (D\partial C/\partial x) - \partial S/\partial t, \quad (1)$$

where C is concentration of diffusing molecular water, t is time, D is the diffusion coefficient, S is the concentration of water molecules which have reacted with the glass matrix and become immobile, and x is depth into the glass. The diffusion coefficient is generally a function of concentration C (Anovitz et al. 1999; Doremus 2002; Rogers 2007a); it also exhibits a temperature dependence approximately given by the Arrhenius equation

$$D = A \exp [-E/(RT)], \quad (2)$$

where A is the pre-exponential rate constant with units of $[\text{length}^2/\text{time}]$, E is the activation energy of the diffusion reaction in J/mol, R is the universal gas constant (8.314 J/mol °K), and T is absolute temperature in °K. Thus, D is time-varying since the temperature undergoes both annual and diurnal variation.

The general solution of equation 1 for variable D requires a two-dimensional numerical integration (Anovitz et al. 1999). However, it can be shown that, for a diffusion coefficient $D(t)$ which varies only in time, the diffusion equation 1 can be solved by a single integral of the diffusion coefficient over time, a much less difficult problem to solve (Crank 1975; Rogers 2007a). For this case, the effective diffusion coefficient D_e over a period of time t is given by (Crank 1975; Rogers 2007a)

$$D_e = (1/t) A \int \exp\{-E/[RT(t')]\} dt'. \quad (3)$$

Since the pre-exponential factor plays no role in the time-varying process, it is convenient for the purposes of analysis to define a normalized hydration rate as $K_e = D_e / A$:

$$K_e = (1/t) \int \exp\{-E/[RT(t')]\} dt'. \quad (4)$$

Although no closed-form solution to this integral is known, it can be solved numerically to any desired accuracy as a finite sum:

$$K_e = (1/N) \sum \exp\{-E/[RT(t_i)]\}, \quad (5)$$

with the sum being taken over the hydration time in N increments of $\Delta t = t_{i+1} - t_i$.

Furthermore, K_e can be used to define an effective hydration temperature (EHT):

$$\text{EHT} = E/[R \ln(K_e)] \quad (6)$$

Thus, if a time-varying temperature history can be modeled numerically, equation 5 can be used to compute an effective hydration rate constant, and an effective hydration

temperature can then be computed by equation 6.

It can also be shown that, for a diffusion-reaction process in which the diffusion coefficient is a function of concentration, the concentration of diffusing molecules is completely defined by the parameter $z = x/(4Dt)^{1/2}$, where x is depth into the obsidian, t is time, and D is the diffusion coefficient (Crank 1975; Rogers 2007a). This leads to the hydration rate equation familiar to archaeologists

$$x^2 = kt \quad (7)$$

where k is proportional to D_e . Although other functional forms have been proposed for this equation (e.g. Basgall 1990; Basgall and Hall 2000; Pearson 1995), no other form is supported by theory or laboratory experiment (Doremus 2000, 2002; Ebert et al. 1991; Stevenson et al. 1989, 1998, 2000, 2004; Zhang et al. 1991). Indeed, Haller observed in 1963 that, if any dependence other than quadratic is found, "it is more likely the fault of the experiment rather than any inherent feature of the diffusion process" (Haller 1963:217).

Computational Approach

The computations employed in equations 5 and 6 are laborious, since they model temperature variations on an hour-by-hour basis (8,760 data points per year). For computations, the model was implemented in Matlab 5.3, but modeling more than a year at a time is not computationally feasible on a PC. However, an algebraic expression for the EHT which is more convenient for computation than equations 5 and 6 is (Rogers 2007a):

$$\text{EHT} = T_a(1 - 3.8 \times 10^{-5} y) + 0.0096 y^{0.95} \quad (8a)$$

where T_a is annual average temperature, and the variation coefficient y is the sum of the squares of the annual and mean diurnal

temperature variation, or

$$y = V_a^2 + V_d^2. \quad (8b)$$

Here V_a is the annual variation, defined as the difference between the July average temperature and the January average temperature, and V_d is the mean diurnal variation, defined as the average of the daily temperature ranges for July and January. The values of V_a and V_d are those at the burial depth of the artifact. If surface temperatures are used in the computation, the parameters must be corrected for depth (e.g. Carslaw and Jaeger 1959: 81); the present computation assumes artifacts on the surface, so V_a and V_d are those for surface conditions. The use of equations 8a and 8b simplifies the computation without significantly detracting from accuracy. For these computations E/R was set equal to 10,000 °K, which is mid-range for typical obsidians (Friedman and Long 1976), and z was assumed to be zero.

The analysis leading to equation 8 assumes T_a , V_a , and V_d are stable. However, if the parameters change over long periods of time, the effect can be approximated as a series of stepwise changes and equation 8 can still be employed as a short cut to compute EHT. Equation 6 must then be used to compute K_e .

The temperature history $T(t_i)$ must be specified to perform this calculation. The technique reported in Rogers 2007a was based on a climate model which included three terms, a constant and two sine terms. The constant term was defined as T_a ; the first sine term, with a period of 12 months, has an amplitude of $V_a/2$; and the second sine term has a period of 24 hours, and an amplitude of $V_d/2$. In the real world, of course, the diurnal and annual variations are only approximately sinusoidal, but the model has been shown to yield accurate results (Rogers 2007c). The validation was performed by comparing the results of EHT computed using the simplified climate model with EHT computed from an 8-

year run of hourly temperature data from the Amargosa Desert Research Site near Beatty, NV. The two techniques yielded EHT results within <1.0°C.

For this analysis, paleoclimatic change is treated as a low-frequency phenomenon affecting T_a . It is possible that high-frequency components were present as well, but they are assumed the same as present-day fluctuations. Thus, for the present case T_a is modeled as constant for 500 years, after which a shift up or down occurs. For each 500 year interval, denoted by i , a value of $K_e(i)$ can be computed from equation 5. The interpretation of $K_e(i)$ is that it represents the hydration rate which prevails during interval i . For hydration analysis, however, we are interested in the effective rate which has occurred since the item was created, which probably includes many 500 year intervals. This rate, $K_m(i)$, can be shown to be the weighted mean of all the coeval and subsequent $K_e(i)$ values, or

$$K_m(n) = \Sigma[K_e(t_i)\Delta t_i]/\Sigma(\Delta t_i) \quad (9)$$

where the sum is taken over all the intervals from 1 to n . If the values of Δt_i are all equal (as they are in this case, at 500 years), equation 9 becomes

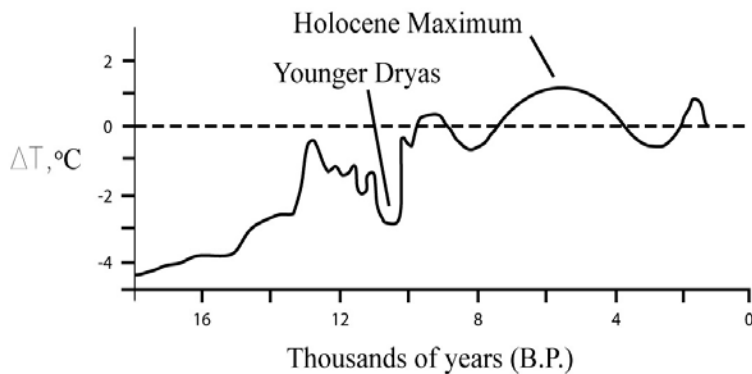
$$K_m(n) = (1/n)\Sigma K_e(t_i). \quad (10)$$

Effective hydration temperature is computed by rearranging equation 6, and substituting K_m for K_e .

Paleoclimate Temperature Profiles

Temperature histories are the critical inputs needed for calculation of EHT and of effective hydration rate. Numerical estimates of mean temperatures for the anathermal and altithermal were derived from those presented in West et al (2007:17, Fig. 2.2), amplified by those of Graumlich (1993) and Soon and Baliunas (2003) for the Medieval Climatic Anomaly and the Little Ice Age. West et al.

Figure 1. Paleotemperature profile, showing deviation of annual average temperature from current conditions. From West et al. 2007.



(2007) show a fluctuation of annual average temperatures of the order of $\pm 1.5^{\circ}\text{C}$; Graumlich (1993) and Soon and Baliunas (2003) also estimated a mean temperature change of the order of 1°C to 2°C . The data of Graumlich (1993) are based on tree rings in the Sierra Nevada, while the West et al. (2007) and Soon and Baliunas (2003) employed landscape-level multiproxy data. The profile of West et al. (2007) is shown in Figure 1, and was used in the model to characterize average annual temperature (T_a).

The climate model used for EHT computation also requires estimates of annual temperature variation (V_a) and mean diurnal variation (V_d). Values of these parameters for present conditions can be computed from current weather records, which are based on a 30 year history. An analysis of 30-year climate temperature histories for 21 meteorological sites in the southwestern Great Basin and northern Mojave Desert demonstrated that the annual variation can be predicted from T_a by the equation

$$V_a = 1.57 + 0.94T_a \quad (11)$$

with an accuracy of $<0.27^{\circ}\text{C}$, 1-sigma (Rogers 2007b). It was further shown that mean diurnal variation (V_d) can be assumed to be 15.4°C with adequate accuracy ($<1.67^{\circ}\text{C}$, 1-sigma) for desert environments, regardless

of altitude. For the paleotemperature model, V_a was computed from equation 11 and V_d was set equal to 15.4°C .

For numerical modeling purposes, variations in mean annual temperature were read from Figure 1 at 500-year intervals. The annual mean temperature for the present was assumed to be 16.0°C , typical of the southwestern Great Basin and northern Mojave Desert. Annual and mean diurnal variations were computed as described above, and the resulting temperature parameter set is presented in Table 1, with the corresponding values of EHT for each 500-year interval computed from equations 8a and 8b.

Table 1. Temperature Parameters

Age, Kyrs	Delta T_a	V_a	V_d	EHT
0.0	0.0	16.6	15.4	19.29
0.5	-0.5	16.1	15.4	18.71
1.0	0.8	17.4	15.4	20.23
1.5	0.8	17.4	15.4	20.23
2.0	0.3	16.9	15.4	19.64
2.5	-0.3	16.3	15.4	18.94
3.0	-0.5	16.1	15.4	18.71
3.5	-0.5	16.1	15.4	18.71
4.0	0.0	16.6	15.4	19.29
4.5	1.0	17.6	15.4	20.47
5.0	1.3	17.8	15.4	20.82
5.5	1.3	17.8	15.4	20.82
6.0	1.2	17.7	15.4	20.70
6.5	1.0	17.6	15.4	20.47
7.0	0.5	17.1	15.4	19.88
7.5	0.0	16.6	15.4	19.29
8.0	-0.5	16.1	15.4	18.71
8.5	-0.5	16.1	15.4	18.71
9.0	0.0	16.6	15.4	19.29
9.5	0.3	16.9	15.4	19.64
10.0	-0.5	16.1	15.4	18.71
10.5	-2.8	14.0	15.4	16.05
11.0	-1.3	15.4	15.4	17.78
11.5	-1.8	14.9	15.4	17.20
12.0	-1.3	15.4	15.4	17.78

Model Results

Model computations were implemented for equations 10 and 6 in Matlab 5.3, based on the input data of Table 1. The EHT values in

Figure 2. Variation of hydration rate, relative to modern value.

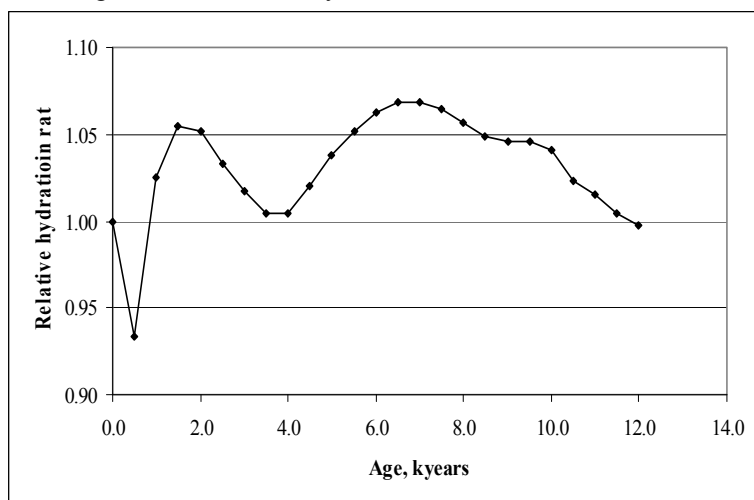


Table 1 were converted into K_e for each 500-year interval by equation 6. Equation 10 was then used to compute the K_m by summing over all subsequent times, yielding the effective value of hydration rate for an artifact originating in that interval. An overall value of EHT corresponding to K_m was then computed from equation 6. Finally, the value of K_m was normalized by dividing it by the value at the present, resulting in Relative K_m , shown in Figure 2. Numerical data are presented in Table 2.

Figure 2 shows that temperature changes probably did affect the hydration rate of obsidian throughout the Holocene to a noticeable degree. The effect is especially significant for the Holocene Maximum around 6,000 years ago, and more recently during the Medieval Climatic Anomaly (MCA) and the Little Ice Age (LIA). Use of the present-day hydration rate is not appropriate in these age ranges. For example, Coso obsidian has a hydration rate of about $23.5 \mu^2/1000$ cal years based on current temperatures at INY-30. Figure 2 shows that, for a 6,500 year old artifact, the average hydration rate should be about 7% higher, or about $25.1 \mu^2/1000$ cal years, and this value should be used in any calculation of age.

Table 2 Variation of hydration parameters over time.

Age, Kyr	RelKm	EHT	RCF
0.0	1.000	19.29	1.0000
0.5	0.934	18.71	1.0357
1.0	1.025	19.50	0.9875
1.5	1.055	19.75	0.9729
2.0	1.052	19.73	0.9744
2.5	1.033	19.57	0.9833
3.0	1.017	19.44	0.9915
3.5	1.005	19.34	0.9975
4.0	1.004	19.33	0.9978
4.5	1.020	19.46	0.9898
5.0	1.038	19.61	0.9812
5.5	1.052	19.73	0.9744
6.0	1.062	19.81	0.9694
6.5	1.069	19.86	0.9664
7.0	1.069	19.86	0.9663
7.5	1.064	19.83	0.9685
8.0	1.056	19.76	0.9723
8.5	1.049	19.70	0.9757
9.0	1.046	19.68	0.9770
9.5	1.046	19.68	0.9771
10.0	1.040	19.63	0.9798
10.5	1.023	19.49	0.9882
11.0	1.015	19.42	0.9925
11.5	1.005	19.33	0.9976
12.0	0.998	19.27	1.0012

An alternative analytical approach used by some researchers is to make the correction to the rim readings rather than to the hydration rate. It is well known that if rims are measured for two artifacts from the same obsidian source but from different sites with differing EHT values, they must be adjusted for EHT to be directly comparable. The benefit of this approach is that the corrected rim values can then be compared with rim values from published data and from other sites. If the EHT is known for a reference site, rim thicknesses from sites with other EHT values can be corrected to the reference site conditions by multiplying them by a rim correction factor (RCF) of approximately

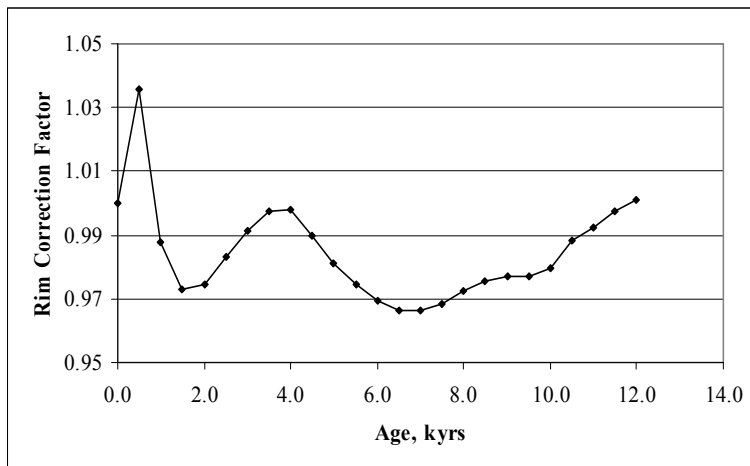
$$RCF = \exp[-0.06(EHT - EHT_z)], \quad (12)$$

where EHT_z is effective hydration

temperature for the reference site (Rogers 2007a).

This same procedure can be used to adjust the rim values to compensate for paleoclimatic change, with EHTz interpreted as the present EHT. The rim correction factors computed from this equation are presented in Table 2, and shown graphically in Figure 3. To use them, one multiplies the measured rim value by the RCF for that age, and then computes age using the present value of hydration rate, $23.5 \mu^2/1000 \text{ cal years}$ for Coso. This has the effect of correcting all the rims from a given site to present temperature conditions.

Figure 3. Variation of rim correction factor, relative to modern value.



Discussion

This analysis shows that temperature shifts in the Holocene can, in fact, exert a measurable effect on obsidian hydration results, causing up to a 7% change in age estimates. Further, the results as presented in Figures 2 and 3 are independent of obsidian source or hydration rate. These conclusions are, of course, based on the assumed temperature variation models of Fig. 1 and Table 1, which generally conform to the Antevs sequence and the postulated temperature profile of West et al. (2007).

Applying the results above requires an iterative procedure, since the changes in

hydration rate or RCF are expressed as a function of age, which is generally unknown. The suggested approach is to, first, compute the age using the present rate value. Second, use Figure 2 or Table 2 to determine the relative hydration rate for an artifact originating in that time interval. Finally, divide the age computed from the modern rate by the relative rate value. For example, for the case of the 6,500-year-old artifact, the rate constant is seen from Fig. 2 and Table 2 to be about a factor of 1.07 greater than at present. Thus, dividing the first estimate of age (6,500 years) by the rate change (1.07) yields about 6,075 years as the improved estimate of age.

The alternative method of correcting using rim correction factor is again to estimate the age using present rate and measured rim, then use Table 2 or Figure 3 to determine the rim correction factor (RCF) appropriate for the estimated age. One then multiplies the age estimate by the square of the RCF. For example, suppose an age of 6,500 years were computed from the rate equation; Table 2 shows the RCF for this age to be about 0.9664. The age estimate is then multiplied by the square of the RCF, which yields $7,000 \times (0.9664^2) = 6,071$ years. The difference in the two procedures is due to round-off errors and is not significant.

As a final point, radiocarbon years and calibrated years can be treated as equivalent for this altithermal correction, because the models for paleoclimatic temperature history, although reasonable, are essentially heuristic. They must, of course, be kept distinct in terms of the rate constant itself when computing age.

Conclusions

The paleotemperature history model employed is relatively crude, but seems to account for the major variations. Further studies are needed to assess the effects of higher-frequency variations as better temperature data become available.

The computations presented here suggest

that the altithermal may, in fact, have exerted an observable influence on obsidian hydration rates, as have other temperature variations during the Holocene. Although the focus was on the altithermal, the data suggest the effects of the MCA and LIA may have been equally significant. For artifacts originating in these intervals, the age estimates based on current conditions could be incorrect by as much as $\pm 7\%$ (too high for the altithermal and MCA, too low for the LIA).

Whichever computational procedure is used (relative hydration rate change or rim correction factor) essentially compensates for the changes in hydration rate caused by the warmer or colder periods. The iterative computational process described above will correct the age computation for the effects of these variations, at least within the limits of the diffusion-reaction model of hydration.

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- A final issue is the construction of hydration rates from obsidian-radiocarbon pairings. In principle, the construction of rates should take these Holocene temperature fluctuations into account. The method for doing so is beyond the scope of this paper, but merits further investigation.
- ## Acknowledgements
- As always, I acknowledge my gratitude and indebtedness to the late Dr. Robert Doremus of the Rennselaer Polytechnic Institute, who literally wrote the book on diffusion-reaction processes in glass, and has been a constant source of advice and counsel. Also, I particularly wish to thank Dr. Brian Andraski and colleagues of the USGS for kindly making available their temperature data from the Amargosa Desert Research Site. Any remaining errors, whether of omission or commission, are mine.
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BY-LAWS OF THE INTERNATIONAL ASSOCIATION FOR OBSIDIAN STUDIES

ARTICLE 1 – NAME

This organization shall be known as the International Association for Obsidian Studies (IAOS).

ARTICLE 2 – PURPOSE

1. The general objective of the IAOS shall be to provide a professional association for those involved in the study of the physical properties and processes that affect natural glasses, including geological formation, geographic distribution, chemical characterization, hydration, and the application of these studies to archaeological and geological problems, including dating.
2. The specific and primary purposes of the IAOS are:
 - a. To establish a forum from which current issues and advances in the study of natural glasses may be presented and discussed.
 - b. To promote awareness and provide informational programs that will aid the archaeological and geological community in becoming more aware of problems and potentials of the application of techniques from the physical and natural sciences in archaeology and geology.
 - c. To promote interdisciplinary research designs in archaeology.
 - d. To encourage research and the preparation of papers and reports on the investigations of natural glasses and the application of the results of such studies to archaeological and geological problems.
 - e. To endeavor to maintain high technical standards in related archaeological and geological studies.
 - f. To assist new and existing laboratories to adopt or conform to acceptable and comparable standards for analysis and reporting.
 - g. To establish a code of conduct directed towards these ends.
 - h. To cooperate with archaeological, geological, and other natural and social scientific associations and societies.
 - i. To advance relations with governmental agencies and the public in general; all without pecuniary profit to any directory, officer, or member.

ARTICLE 3 – POWERS

1. IAOS shall have the power to receive, administer, and disburse dues, assessments, and other grants to further its ends; to acquire, hold absolutely or in trust for the purposes of the IAOS; to publish newsletters, reports, bulletins, journals, and monographs; to affiliate with other organizations in the pursuit of common aims, and to appoint delegates or representatives to such organizations; to establish branches, sections, or divisions, on a regional or functional basis; and to engage in such other activities as are in keeping with the objectives of the association.
2. No part of the net receipts of the IAOS shall insure to the benefit of or be distributable to its members, officers, committee members, or other private persons, except that the association shall be authorized and empowered to pay reasonable compensation for services rendered and to make payments and distributions in furtherance of the purposes of the IAOS as set forth in these By-laws.
3. No substantial part of the activities of the IAOS shall be the carrying on of propaganda or otherwise attempting to influence legislation, and the IAOS shall not participate in, or intervene in (including the publishing or distribution of statements) any political campaign on behalf of the candidate for public office.

ARTICLE 4 – MEMBERSHIP

1. Membership in the IAOS is open to any person in sympathy with the objectives of the IAOS, as set forth in Article 2, without regard to age, sex, race, religion, or nationality.
2. The IAOS may have several classes of membership as determined by a vote of the membership. Membership shall consist of Regular Members, Lifetime Members, and Student Members. Each member shall have one vote in the transaction of the business of the IAOS and shall be eligible for any elected or appointive office in the IAOS, subject only to restrictions defined elsewhere in these By-laws.
 - a. Regular Members
 1. Regular Members are those persons or organizations interested in obsidian studies or who perform obsidian studies. Regular members may, for instance, be archaeologists involved in applying or using obsidian data for archaeological interpretations.
 - b. Lifetime Members
 1. Lifetime Members pay a one-time fee determined by the Executive Board and receive a membership that is active for the lifetime of the member or lifetime of the IAOS.
 2. Lifetime Members are a special category of Regular Members and maintain the same rights and privileges as Regular Members.
 - c. Student Members

1. Student Members enjoy all privileges of Regular Members. Students will receive a year's free membership if they submit either an obsidian-related article for publication in the Newsletter or an abstract of such article published elsewhere. Students are eligible for membership for a lower fee.
3. The Executive Board may, by a three-quarters vote, remove from the membership rolls any member whose acts are contrary to the ideals, objectives, and accepted standards of the IAOS as set forth in Article 2, and the code of conduct established by vote of the membership of the IAOS. The action of the Executive Board may be subject to an appeal to the IAOS membership at its Annual Meeting.
4. The Secretary-Treasurer shall be empowered to discontinue the membership of any person or organization for non-payment of dues for the annual membership.
5. No member shall be personally liable to any creditor of the IAOS for any indebtedness of liability, and any and all creditors shall look to the IAOS assets for payment.
6. The use of IAOS membership contact information is only for purposes that accord with the general objectives described in these by-laws. Decisions regarding use of the membership contact information shall be made by the Executive Committee. Except for regular distribution of the newsletter by the Newsletter Editor, only the Secretary-Treasurer or the President shall send emails using the IAOS email list.

ARTICLE 5 – ORGANIZATION

1. The Officers of the IAOS shall consist of a President, a Vice-President/President Elect/Past-President, a Secretary-Treasurer, the Newsletter Editor, and the Webmaster, representing no fewer than two institutions or laboratories.
2. IAOS policies and directions shall be established by the Executive Board, the Advisory Board of Directors, and other IAOS members selected by the Executive Board.
3. The President shall serve as the IAOS's chief executive officer and its representative in official affairs and transactions. The President shall make certain that all resolutions of the Executive Board are implemented.
4. The Vice-President shall be elected for one year, at the conclusion of which he/she shall succeed to the office of President to serve a two year term. He/she will then serve one year as Past President.
5. The Secretary-Treasurer shall be elected for a two-year term, and may be renewed consecutively either by majority vote of the IAOS or by unanimous decision of the remainder of the Executive Board.
6. The Executive Board of the IAOS shall consist of the President, Vice President, Secretary-Treasurer, the Newsletter Editor of the IAOS.

7. No restriction is placed on officers seeking election to the same office in which he/she has previously served, nor a different office within the IAOS, provided that terms of the President office are not served consecutively.
8. In the event of the absence, death, resignation, or incapacity of the President, the Vice President shall assume the duties of the President for the remainder of the President's term.
9. The offices of President, Vice President, and Secretary-Treasurer shall be elected by a majority vote of the IAOS members.

ARTICLE 6 – DUTIES OF THE OFFICERS

1. President

- a. The President shall serve as the IAOS's chief executive officer and its representative in official affairs and transactions. The President shall make certain that all resolutions of the Executive Board are implemented. The President shall preside over all meetings of the IAOS. If the President cannot attend a meeting, the Vice President shall preside in his/her place. The President shall have the usual appointive power and shall exercise all the duties and responsibilities commonly associated with this office, except as provided by the By-laws.
- b. The President may appoint representatives of the IAOS to other societies, agencies, or councils or select such representatives from slates submitted by other societies and agencies.
- c. Acting in consultation with the Vice President, the President shall appoint all necessary committees and define their duties.
- d. Acting in consultation with the Vice President, the President shall appoint all necessary committees to represent the interests of the IAOS in that region.
- e. The President, Vice President, and Secretary-Treasurer shall sign all written contracts authorized by majority vote of the Executive Board or the IAOS members at an Annual Meeting, or by special mail or email ballot, except for basic contracts for printing, and other matters necessary to routine publication, as well as contracts for products or services to be provided at IAOS sponsored events. Such contracts may be signed by the President, Vice President or Secretary-Treasurer.
- f. The actions of the President in exercising the duties and responsibilities of the office shall be subject to review and approval of the Executive Board.

2. Vice President

- a. The Vice President shall consult with and assist, as appropriate, the President in completing his/her duties.
- b. The Vice President shall preside over all meetings at which the President in cannot attend and shall assume the President's responsibilities for the duration of that meeting.
- c. The Vice President shall assume the title and duties of the President after serving his/her term as Vice President.

3. Secretary-Treasurer

- a. The Secretary-Treasurer, subject to the directives of the President in consultation with the Vice President, shall be responsible for maintaining contact with the President and Vice President, have charge of administrative matters under the direction of the President, be responsible for the administration of the finances of the IAOS subject to provisions in these By-laws. Duties of the Secretary-Treasurer are to:

1. Announce all meetings to the membership of the IAOS, either by mail, email, or through the IAOS Newsletter.
2. Maintain and distribute minutes of all meetings to the Executive Board.
3. Keep and update membership rolls of the IAOS on both electronic and written media, maintaining a minimum of two backup copies of electronic membership, By-laws, Working Policies, and other documents authorized or adopted by the IAOS
4. Maintain records of all financial transactions in accordance with standard bookkeeping practices.
5. Have custody of all money and securities for the IAOS.
6. Assemble and mail or email articles, and announcements to the membership.
7. Mail/email and receive applications for membership.
8. Conduct elections as described in Article 9.

- b. The Secretary-Treasurer is directed to correspond with every IAOS members each year, encouraging them to renew their membership, informing them of any changes in annual dues, IAOS activities, and officers. This correspondence may be included in a bulletin or newsletter that discusses other IAOS matters.

- c. As soon as possible following the Annual Meeting, the Secretary-Treasurer will mail or email to all members of the Executive Board a copy of the current By-laws, a copy of the minutes of the Executive Board and Annual Meeting, and a copy of membership materials and IAOS stationary.

4. Newsletter Editor

- a. The Newsletter Editor shall be responsible for the coordination, editing, and production of the IAOS Newsletter.
- b. The Newsletter Editor shall coordinate with the Secretary-Treasurer to update the annual membership list for distribution of the IAOS Newsletter.

5. Any duty or responsibility delegated to any officer or member may be temporarily re-delegated by mutual consent of the President and Vice President, or re-delegated for the duration of the elected year by a majority vote of the membership, or a majority vote of the Executive Board.

ARTICLE 7 – EXECUTIVE BOARD

1. Subject to the general directives and limitations imposed by the membership at the Annual Meetings or by mail/email ballot, the Executive Board shall have authority to execute on behalf of the IAOS all powers and functions of the IAOS, as defined by these By-laws.
2. The Executive Board may hold special meetings at the request of the President.
3. A Quorum of the Executive Board shall consist of the President, Vice President, and Secretary-Treasurer of the IAOS.
4. Questions shall be decided by the Executive Board by a majority of the votes cast at any meeting and /or by mail or email ballot. In the case of a tie vote, the decision of the President shall be final. If a member of the Executive Board is unable to attend a meeting, the member may, by written authorization, appoint any active member of the IAOS to serve as proxy for that meeting. But no person by virtue of holding proxies shall have the right to cast more than one vote.
5. The President may on his/her own initiative, or shall at the written request of any member of the Executive Board, ask the Board to vote on specific questions by mail/email ballot. Ballots shall be mailed/mailed by the Secretary-Treasurer who shall specify on the ballots the date on or before which they are to be placed in the mail or emailed to the Secretary-Treasurer. This date shall not be less than fifteen (15) days from the date they were placed in the mail or emailed nor more than thirty (30) days from the date they were placed in the mail or emailed by the Secretary-Treasurer.
6. Reports of officers, representatives, delegates, committees, and agents shall be approved by the Executive Board. At the discretion of the Executive Board, these reports may be presented in full or in brief at the Annual Meeting.
7. The Executive Board shall act upon the budget provided by the Secretary-Treasurer. A budget shall be submitted to the Executive Board at the Annual Meeting for approval.

ARTICLE 8 – ADVISORY BOARD OF DIRECTORS

1. An Advisory Board of Directors shall be nominated by the Executive Committee. This board will normally be composed of those senior researchers who have made important and life-long contributions to obsidian research. These Directors shall receive Lifetime Member status and shall be permanently installed unless declined by the individual. These Directors may be called upon by the Executive Committee from time to time for advice on any topic relevant to the goals of the IAOS.

ARTICLE 9 – ELECTIONS

1. Before December 1 of each year or January 1 for March-April election, the Secretary-Treasurer shall submit an announcement of election of new officers in the IAOS Newsletter. This announcement shall solicit nominations and provide information regarding the election process.
2. Officers are elected for terms running one or two years beginning at the time of the Annual Meeting until the following Annual Meeting.
3. Any person receiving two or more nominations shall, upon acceptance of the nomination, be placed on the ballot. If no nominations are received by the Secretary-Treasurer, nominations will be solicited at the Annual Meeting. Each nomination at the Annual Meeting must be supported by a second.
4. Each active member shall be entitled to vote for one candidate for each office. The election shall be conducted by mail or email prior to the Annual Meeting.
5. Officers shall be elected by a simple majority vote of ballots received.
6. The results of any elections shall be announced at the Annual Meeting.
7. Any officer or member of the Executive Board may be removed for cause or without cause at any Annual or Special Meeting of the IAOS by a two-thirds (2/3) vote of members in good standing present, provided that notice of such proposal shall have been stated in the announcement of the meeting.
8. If an officer is unable to complete the term of office, the Executive Board, by Special Meeting, ballot, email, or telephone conference, may appoint a member to fill the unexpired term, so long as not inconsistent with other provisions of these By-laws.

ARTICLE 10 – MEETINGS

1. The IAOS shall hold Annual Meetings at times and places designated by the Executive Board, although the IAOS shall hold at least one annual meeting. The location and date for the meeting for the subsequent year will be determined at the Annual Meeting.
2. In general, the location and time for the Annual Meeting will be determined by the geographic distribution of members, to ensure maximum participation and minimize inconvenience for the majority of Institutional members. When appropriate, Annual Meetings will be scheduled to coincide with other professional meetings (e.g., Society for American Archaeology Annual Meetings; International Symposium on Archaeometry) to provide an economy of travel and increase opportunities for participation.
3. Due notice of the place and time of the ensuing Annual Meeting along with an optional agenda shall be published in the IAOS Newsletter and mailed to all active members no later than the announcement soliciting nominations for new officers.

4. The attending members of the Annual Meeting shall constitute a Quorum.
5. The business of the IAOS shall be discussed at the Annual Meeting. The order of business at the Annual Meeting shall be as determined by the President. Papers and other matters of scientific interest, as well as symposia, may be presented at the Annual Meeting.
6. Special Meetings of the IAOS shall be called by the President at any time the Executive Board or the general membership so directs by a majority vote. Special Meetings may be held in person, by email, on a telephone conference call, or Internet web meeting, or in another manner in which the meeting is easy and cost-effective form members to attend. Any matter of business may be decided at a Special meeting, provided notice of such business was specified in the call. Special Meetings may not be called with less than thirty (30) days notice to all members of the Executive Board.
7. Special Meetings of the Executive Board may be held at the call of the President, in consultation with the Vice President, or upon written or email request of at least three (3) members of the Executive Board. Special Meetings of the Executive Board may not be called less than fifteen (15) days notice to all members of the Board.
8. All matters of the business of the IAOS may be decided by means of a referendum vote by mail or email ballot under conditions specified in these By-laws.
9. The President may rule on questions of order and procedure coming before the meeting or submit such questions to the vote of the meeting.
10. At its Annual Meeting, the following tasks should be accomplished:
 - a. Any amendments to the By-laws must be proposed and voted upon, if at least 10 members, including two officers are present.
 - b. The IAOS budget needs to be reviewed and approved, as appropriate, by vote from the Executive Board and/or membership.
 - c. Review and discuss, as appropriate, the goals and objectives of the IAOS, and activities toward achieving those goals.
11. Coordination of the arrangements and program for the Annual Meeting is vested in a standing committee consisting of the President, Vice President, and Secretary-Treasurer of the IAOS.
12. Official sponsorship of scientific symposia presented at another meeting (i.e. Society for American Archaeology) shall be given after consideration by the Executive Committee., The Executive Committee may seek a majority vote of the body.

ARTICLE II – FINANCES

1. The fiscal year of the IAOS shall run from January 1 to December 31.

2. A dues assessment, to be levied on an annual basis, shall be established by the Executive Board.
3. The annual dues structure may vary, according to the type of membership (e.g. Student Member, Regular Member).
4. Dues shall be payable on January 1 of each year.
5. Failure to pay dues by 180 days after January 1 of the year in which they become due will result in automatic dismissal of a member.
6. The funds of the IAOS shall be deposited in the name of the IAOS in such bank or trust company as the Secretary-Treasurer shall designate and shall be drawn out by checks, drafts, or other orders for the payment of money signed by the Secretary-Treasurer or by such person or persons as shall be designated by the Executive Board. Any expenses related to official IAOS business, such as routine expenses for IAOS Bulletin mailings, IAOS Annual Meeting or event support, over the amount of \$250, or expenses of any amount that are outside of regular IAOS business, shall require prior approval from the IAOS Executive Board.
7. All deeds, mortgages, releases, conveyances, contracts, or other instruments of the IAOS authorized by the Executive Board shall be executed on behalf of the Council by the officer or officers authorized by the Executive Board. Said officer or officers shall be authorized to accept gifts of money or kind on behalf of the IAOS and to deposit these with the funds of the IAOS or hold them in trust pending instructions by the Executive Board.
8. The income from annual dues and from investments and other sources shall constitute the working fund of the IAOS, available for operating, publications, and other current expenses consistent with the purposes of the IAOS as the Executive Board may direct.
9. No financial obligation in excess of the funds available in the treasury shall be assumed by the Executive Board or by any officer on behalf of the IAOS except when approved by a two-thirds vote of the members of the IAOS present at a regular Annual Meeting or at a Special Meeting, provided that for the purpose of this section, estimated receipts from annual dues and other accounts receivable for the current year may be considered available funds.

ARTICLE 12 – DISPOSAL OF ASSETS

1. Upon the dissolution of the IAOS, whether voluntary or involuntary, after paying all of the liabilities of the IAOS, the IAOS shall dispose of its assets exclusively for the scientific and educational purposes set forth in these By-laws by donating them to an institution or organization exempt from taxation under paragraph 503 c (3) of the Internal Revenue Code of 1954 (or the corresponding provision of such future Internal Revenue laws as may be in effect).

ARTICLE 13 – AMENDMENTS

1. The By-laws may be amended by a two-thirds vote of the members present at a business meeting of the Annual Meeting or at a Special Meeting called in accordance with Article 10, paragraph 3. The By-laws may also be amended by mail or email ballot provided that a proposed amendment is approved by two-thirds vote of the votes cast.
2. Amendments may be proposed by the Executive Board or by any ten (10) members of the IAOS. The proposed amendments shall be mailed or emailed to the members of the IAOS by the Secretary at least thirty (30) days before an Annual Meeting or Special Meeting. In the case of a mail ballot upon an amendment, members shall address ballots to the Secretary and place them in the mail and postmarked not more than thirty (30) days from the date they were mailed out and postmarked by the Secretary. An amendment shall go into effect immediately upon approval unless otherwise specially provided.
3. The provisions of these By-laws, as amended, shall be effective immediately upon their adoption and shall supersede and nullify all previous enactments in conflict with them.

ABOUT OUR WEB SITE

The IAOS maintains a website at <http://www.peak.org/obsidian/>

The site has some great resources available to the public, and our webmaster, Craig Skinner, continues to update the list of publications and must-have volumes.

You can now become a member online or renew your current IAOS membership using PayPal. Please take advantage of this opportunity to continue your support of the IAOS.

Other items on our website include:

- World obsidian source catalog
- Back issues of the *Bulletin*.
- An obsidian bibliography
- An obsidian laboratory directory
- Photos and maps of some source locations
- Links

Thanks to Craig Skinner for maintaining the website. Please check it out!

CALL FOR ARTICLES

Submissions of articles, short reports, abstracts, or announcements for inclusion in the *Bulletin* are always welcome. We accept electronic media on CD in MS Word. Tables should be submitted as Excel files and images as .jpg files. Please use the *American Antiquity* style guide (available at www.saa.org/publications/StyleGuide/styFrame.html) for formatting references and bibliographies.

Submissions can also be emailed to the *Bulletin* at cdillian@princeton.edu. Please include the phrase "IAOS Bulletin" in the subject line. An acknowledgement email will be sent in reply, so if you do not hear from us, please email again and inquire.

Deadline for Issue #43 is May 1, 2010.

Send submissions to:

Carolyn Dillian
IAOS *Bulletin* Editor
c/o Princeton University
Princeton Writing Program
Whitman College
South Baker Hall
Princeton, NJ 08544
U.S.A.

Inquiries, suggestions, and comments about the *Bulletin* can be sent to cdillian@princeton.edu. Please send updated address information to Colby Phillips at colbyp@u.washington.edu

MEMBERSHIP

The IAOS needs membership to ensure success of the organization. To be included as a member and receive all of the benefits thereof, you may apply for membership in one of the following categories:

Regular Member: \$20/year*

Student Member: \$10/year or FREE with submission of a paper to the *Bulletin* for publication. Please provide copy of current student identification.

Lifetime Member: \$200

Regular Members are individuals or institutions who are interested in obsidian studies, and who wish to support the goals of the IAOS. Regular members will receive any general mailings; announcements of meetings, conferences, and symposia; the *Bulletin*; and papers distributed by the IAOS during the year. Regular members are entitled to vote for officers.

*Membership fees may be reduced and/or waived in cases of financial hardship or difficulty in paying in foreign currency. Please complete the form and return it to the Secretary-Treasurer with a short explanation regarding lack of payment.

NOTE: Because membership fees are very low, the IAOS asks that all payments be made in U.S. Dollars, in international money orders, or checks payable on a bank with a U.S. branch. Otherwise, please use PayPal on our website to pay with a credit card. <http://www.peak.org/obsidian/>

For more information about the IAOS, contact our Secretary-Treasurer:

Colby Phillips
IAOS
c/o University of Washington
Department of Anthropology
Box 353100
Seattle, WA 98195-3100
U.S.A.
colbyp@u.washington.edu

Membership inquiries, address changes, or payment questions can also be emailed to colbyp@u.washington.edu

ABOUT THE IAOS

The International Association for Obsidian Studies (IAOS) was formed in 1989 to provide a forum for obsidian researchers throughout the world. Major interest areas include: obsidian hydration dating, obsidian and materials characterization ("sourcing"), geoarchaeological obsidian studies, obsidian and lithic technology, and the prehistoric procurement and utilization of obsidian. In addition to disseminating information about advances in obsidian research to archaeologists and other interested parties, the IAOS was also established to:

1. Develop standards for analytic procedures and ensure inter-laboratory comparability.
2. Develop standards for recording and reporting obsidian hydration and characterization results
3. Provide technical support in the form of training and workshops for those wanting to develop their expertise in the field
4. Provide a central source of information regarding the advances in obsidian studies and the analytic capabilities of various laboratories and institutions.

MEMBERSHIP RENEWAL FORM

We hope you will continue your membership. Please complete the renewal form below.

NOTE: You can now renew your IAOS membership online! Please go to the IAOS website at <http://www.peak.org/obsidian/> and check it out! Please note that due to changes in the membership calendar, your renewal will be for the next calendar year. Unless you specify, the *Bulletin* will be sent to you as a link to a .pdf available on the IAOS website.

___ Yes, I'd like to renew my membership. A check or money order for the annual membership fee is enclosed (see below).

___ Yes, I'd like to become a new member of the IAOS. A check or money order for the annual membership fee is enclosed (see below). Please send my first issue of the IAOS *Bulletin*.

___ Yes, I'd like to become a student member of the IAOS. I have enclosed either an obsidian-related article for publication in the IAOS *Bulletin* or an abstract of such an article published elsewhere. I have also enclosed a copy of my current student ID. Please send my first issue of the IAOS *Bulletin*.

NAME: _____

TITLE: _____ AFFILIATION: _____

STREET ADDRESS: _____

CITY, STATE, ZIP: _____

COUNTRY: _____

WORK PHONE: _____ FAX: _____

HOME PHONE (OPTIONAL): _____

EMAIL ADDRESS: _____

My check or money order is enclosed for the following amount (please check one):

___ \$20 Regular

___ \$10 Student (include copy of student ID)

___ FREE Student (include copy of article for *Bulletin* and student ID)

___ \$200 Lifetime

Please return this form with payment to:

Colby Phillips

IAOS

c/o University of Washington

Department of Anthropology

Box 353100

Seattle, WA 98195-3100

U.S.A.